QoS Based OVPN Connection Set up and Performance Analysis

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Abstract: - Due to high demand of optical virtual private network (OVPN) connection setup with guaranteed quality of service (QoS) requirement, it is necessary to provide such application by the provider network. In order to support this we propose a QoS based OVPN connection set up mechanism over WDM network to the end customer, which also maintains the minimum blocking probability. The proposed WDM network model can be specified in terms of QoS parameters such as bandwidth and delay. We estimated those QoS parameters based on available resources and QoS requirements in terms of quality factor (Q-Factor). In this mechanism the OVPN connections also can be created or deleted according to the availability of the resources. In this paper we have considered the effect of polarization mode dispersion for the computation of Q-Factors which is prominent effect at high speed networks. The goal of the work is to dynamically provide a best OVPN connection during frequent arrival of connection requests with QoS requirements.

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Key-Words: - OVPN Connection, QoS, Q-Factor, Disjoint Path, Shortest Path, Blocking Probability.

1 Introduction

Now-a-days the research interests mostly concentrate on the dynamic light path/OVPN (Optical Virtual Private Network) provisioning in Optical WDM (Wavelength Division Multiplexing) network which would satisfy the ever growing traffic demand from the end customer/client and results in the efficient utilization of the resources in the network [1]. Due to the increase of traffic load and the Signal quality guaranteed transmission requirement, the recent work going on is the light path/OVPN provisioning in order to satisfy the client requirement [2].

OVPN over IP (Internet Protocol)/GMPLS (Generalized Multiprotocol Label Switching) over DWDM (Dense Wavelength Division Multiplexing) technology with QoS assurances is considered as a promising approach in the next generation OVPN [3, 4]. Now-a-days, WDM and DWDM network have become extremely popular technologies with service providers, as they enable network capacity expansion without laying more fibers. By using WDM /DWDM technology, optical amplifiers and Optical Add Drop Multiplexers (OADMs), service providers can support several generation of optical technology without having to overhaul their fiber back bone networks [5], and they can expand the capacity of any given link by simply upgrading the multiplexers and demultiplexers at each end. As the result WDM/DWDM is now common place in service provider’s core networks. The GMPLS suite for routing and signaling protocols is currently the only technology that provides mechanisms for supporting the provisioning of connections in optical networks [6].

In this paper a new algorithm for provisioning of high speed OVPN connection is proposed by considering the effect of polarization mode dispersion (PMD) in fiber which is a dominant impairment factor at high speed transmission [7-10]. At the time of efficient provisioning of OVPN connection various linear and non-linear impairment factor has to be considered. Without physical impairment awareness, a network layer provisioning algorithm should not guarantee signal quality. Some of the important linear impairments are Polarization mode dispersion, group velocity dispersion (GVD), component cross talk, etc.; and some of the important non-linear impairments are four wave mixing (FWM), self-phase modulation (SPM), cross phase modulation (XPM), scattering etc. At high speed transmission PMD is the most dominant impairment factor in optical fiber [5]. In polarization mode dispersion the two polarization state of fundamental mode may propagate at slightly different group velocities due to asymmetries in fiber which results in pulse broadening of signal and then the limitation the bit rate of the transmission.

In the paper, we have considered various QoS parameters such as bandwidth, differential time delay, physical layer impairment (PLI) constraints, dispersion, spectral width and wavelength of light and formulated Q-Factor model for the OVPN connection setup. We also estimated the QoS requirement such as bandwidth and delay from the client for an OVPN connection in terms of Q-Factor. The proposed algorithm defines a mechanism for effective OVPN provisioning by comparing the requirement of client and the available resources of the network.

2 Related Works

Similar works has been reported in [4, 7-10, 11-17]. The paper [4] suggest a multicast optical level switched path (OLSP) establishment mechanism for supporting high bandwidth multicast services in OVPN and also suggest an entire OVPN control mechanism to adapt the operation of the routing and signaling protocols of GMPLS. The papers [7-10] studied on the effect of polarization mode dispersion at high speed optical fiber channels. The differentiated services architecture [11] works with aggregated flows based upon the notion of per hop behaviours. It takes static decision for the re-routing of specific flows. RSVP [12] defines a purely flow based protocol to ensure about the individual flow requirements. Another issues reported in [13], which says how Bandwidth broker works centrally and provides QoS to the clients. The papers [14-16] say about the distributed protocols for WDM. The paper [17] says particularly on QoS based VPN on optical WDM network. It explain about traffic based guaranteed QoS which is fully wavelength and number of applicant dependent. In all the above reported works the implication of end-to-end QoS support based on quality parameter such as delay and bandwidth in IP-WDM domain are not been considered. But none of this paper concentrated on the bandwidth and differential delay based Q-Factor calculation and the OVPN connection provisioning mechanism based on the Q-Factor requirement of client.

3 System Model

The OVPN system model is shown in Fig 1. This network model consisting of two layers: the Provider edge layer and the Optical core layer [18, 19]. As shown in the model, provider edge router (PER) belongs to an OVPN client which provides OVPN service and interface between client and optical core router (OCR). An OCR is not connected to a client directly. The provisioning of OVPN is the establishment of the tunnels, which may be constructed at layer 1, layer 2 and layer 3 as mentioned in Table 1 for classical layering structure.

Table 1 Classical Layer Structure

Application Layer	
Presentation Layer	
Session layer	SOCKS
Transport Layer	
Network Layer	IPSec, Layer 3 OVPN
MAC Layer	ATM, FR, Layer 2 OVPN
Physical Layer	Layer 1 OVPN

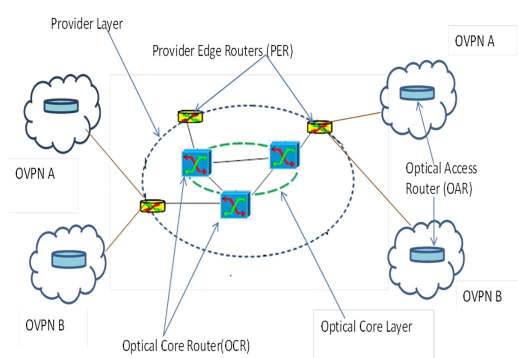


Fig. 1 OVPN System

The optical layer provides point-to-point connectivity between routers in the form of fixed bandwidth circuits, which is termed as light-paths. The collection of light-paths therefore defines the topology of the virtual network interconnecting routers. In provider layer the PER are responsible for all the non-local management functions such as management of optical resources, configuration and capacity management, addressing, routing, topology discovery, traffic engineering, and restoration etc. The provider layer controls all the traffic corresponding to both client and optical layers. PER maintains a traffic matrix (TM) for all the connected OVPN clients within its domain of control. The TM maintains the network as well as physical layer impairment (PLI) constraints such as bandwidth, delay, dispersion and Q-Factor matrices for all the possible OVPN connection in the network, belonging to all the layers. In the following sections we outline our algorithms that carry out the computations necessary for the decisions that lead to provisioning/de-provisioning of OVPN connection.

4 Problem Formulations

Network may be modeled [20, 21] using nodes/routers and links, which provides the layout pattern of interconnections of the various elements like links, nodes, etc. of a network system which is shown in Fig 2. In a network, a node is a connection point, either a redistribution point or an end point for data transmissions. Nodes are represented by the coordinate system where the location of a node is given by point in a coordinate system. Link in a network is a connection through optical fiber link between two nodes.

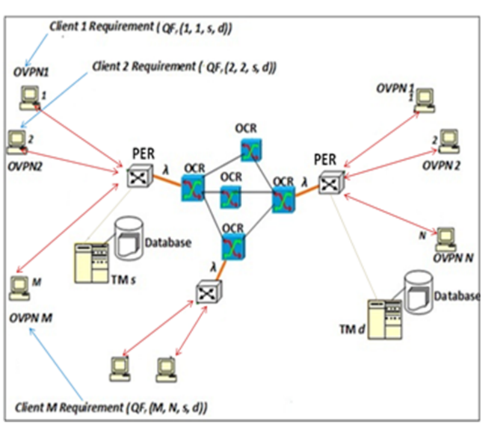


Fig. 2 Network architecture

Connectivity in a system: Connectivity is determined by the connection between two nodes/routers. If there is a link present between two nodes connectivity is taken as '1' otherwise it is taken as '0'. Using this connectivity matrix, light-path can be determined.

If i and j are the node/router pairs, then the connection matrix $T(i, j)$ can be as follows

$$T(i,j) = \begin{cases} 1 & \text{If link between } i \text{ and } j \text{ is exist} \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

If the λ (i, j) is the wavelength matrices between i and j, then, it can be represented as follows

$$\lambda(i,j) = \begin{cases} 1 & \text{If } \lambda \text{ is available between } i \text{ and } j \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

In this algorithm the problem of light path provisioning is based on the Q-Factor requirement of the client and the existing traffic in the network. The various QoS parameters that have to be specified are bandwidth, differential time delay between the two modes in fiber and Q-Factor for each light path. In the following section we formulated few things such as i) Required Q-Factor on client point of view, ii) Computed Q-Factor on System/network point of view. iii) Blocking probability, iv) Optimized OVPN connection setup.

4.1 Estimation of Required Q-Factor

We consider a virtual topology model shown in Fig 2. In this model, a number of connection request for different applications are multiplexed at the source PER i to destination PER j for a light path. This formulation is for the provisioning and de-provisioning of data-path based on the client requirements and available resources. The problem formulations are based on different QoS parameters such as, bandwidth and delay in terms of required Q-Factor, which are explained in following sections. We defined the link cost as the ratio of bandwidth and delay, which is termed as Q-Factor.

Assume every OVPN client end point is attached to at most one PER. In Fig 2, suppose an application for an OVPN client *m* and *n* of source-destination pair (*s, d)* has bandwidth requirement of *B (m, n, s, d)* and the delay requirement of *D (m, n, s, d)*.

If the $QF_r(m,n,s,d)$ is the required Q-Factor, which can be formulated as follows [22].

$$QF_r(m,n,s,d) = \frac{B(m,n,s,d)}{D(m,n,s,d)} \qquad (3)$$

4.2 Estimation of Computed Q-Factor

Assume the physical layer constraints are polarization mode dispersion and link length. If $DS_{PMD}(i, j)$ is the dispersion of the fiber and *L (i, j)* is the length of the fiber link pair *(i, j)*, the bandwidth matrix can be defined as follows [10].

$$B(i, j) = \frac{\sigma}{DS_{PMD}(i, j) \times \sqrt{L(i, j)}} \qquad (4)$$

Where σ represents the pulse broadening factor should typically be less than 10% of a bit time slot for which polarization mode dispersion can be tolerated. The differential time delay between the two modes in fiber link can be calculated as follows [9].

$$D_{PMD}(i, j) = DS_{PMD}(i, j) \times \sqrt{L}(i, j) \qquad (5)$$

If *QF (i, j)* is the computed Q-Factor for a link pair *i* and *j*, then it can be represented as follows.

$$QF(i, j) = \frac{B(i, j)}{D_{PMD}(i, j)} \qquad (6)$$

If *p(s, d)* is the OVPN connection path for a source (*s*) and destination (*d*) pair, then computed Q-Factor for the path can be formulated as follows.

$$QF_C(m,n,s,d) = Min\{QF(i, j)\}, \forall (i, j) \in p(s,d) \qquad (7)$$

Where, *i* and *j* are the node/route pair in a link.

4.3 Estimation of Blocking Probability

Assume *TNCR (m, n, s, d)* is the total number of connection requested for a source (*s*) and destination (*d*) of (m, n) OVPN clients, *TNCB (m, n, s, d)* is the total number of connection blocked, then the blocking probability *BP (m, n, s, d)* can be defined [23] as follows.

$$BP(m,n,s,d) = \frac{TNCB(m,n,s,d)}{TNCR(m,n,s,d)} \times 100 \qquad (8)$$

4.4 Optimized OVPN Connection Setup Mechanism

In this section the optimized OVPN setup mechanism has been mentioned, which means the provisioning OVPN connection request depending on the required and computed Q-Factor. If the required Q-Factor is satisfied by one of the computed connections, then that connection will be fixed for a client, otherwise the request will be blocked.

Let there be an *N* number of OVPN connections for a given source *s* and destination *d* pair, then the Q-Factor of k^{th} OVPN connection can be represented as $QF(OVPN^k_{(m,n,s,d)})$ where k is the OVPN connection reference numbers i.e., *k = {1, 2, 3,. . ., N}* and *N* is the total number of connections.

The main objective of our work is to find an optimal OVPN connection. This objective function can be expressed as follows.

$$QF_c(m,n,s,d) = Max\{QF(OVPN^k_{(m,n,s,d)})\}, \forall k \in \{1,2,\ldots,N\} \qquad (9)$$

The mechanism of optimized OVPN provisioning can be explained mathematically as follows.

$$QF_r(m,n,s,d) \leq QF_c(m,n,s,d) \qquad (10)$$

The provisioning of OVPN connection request will be blocked for the following two cases.

Case 1:

$$QF_r(m,n,s,d) > QF_c(m,n,s,d) \qquad (11)$$

Case 2:

$$\lambda(m,n) = 0 \qquad (12)$$

Where, λ *(m, n)* is the status of available wavelength at any of the connections between *s* and *d*. Equation 10 says about the busyness of all the available computed connections, which means, there is no availability of wavelength at any of the computed OVPN connections.

5. Algorithms and Flowchart

In our work, we evaluate the OVPN connection set up mechanism by considering i) Conventional Shortest path (SP) Computation, ii) Disjoint path (DP) computation.

The proposed algorithms provide an OVPN connection to the client depending on their QoS requirements. The following section explains about the above algorithm.

5.1 OVPN Connection Setup Using Shortest Path

STEP 1: Find all possible OVPN connections for a connection request.

STEP 2:Find the Shortest Distant OVPN connection from all possible OVPN connections s and computed Q-Factor.

STEP 3: Compare the required Q-Factor value of the connection request to the computed Q-Factor value of the OVPN obtained in STEP3.

STEP 4: If it is satisfied then go to STEP 5, otherwise go to STEP 7.

STEP 5: Check whether the selected OVPN is busy or not. If busy the call will be blocked. Go to STEP 1 for next connection request, otherwise go to STEP 7.

STEP 6: The call is blocked. Go for next connection request. Go to STEP 1.

STEP 7: Assign the selected OVPN connection to the requested connection. Go to STEP 1 for next connection request.

The algorithm also can be explained clearly with the help of Flowchart as mentioned in Fig 3. In next section explain about the OVPN connection finding using disjoint path mechanism. The disjoint path mechanism comes from all possible path computation, which computes all possible connections for a given source and destination pairs and later on again some of the connections are computed, which are disjoint in nature.

5.2 OVPN Connection Setup Using Disjoint Paths Mechanism

STEP 1: Find all possible OVPN connections for a connection request.

STEP 2: Find all disjoint OVPN connections from all possible OVPN connections and compute their Q-Factor.

STEP 3: Arrange all the disjoint OVPN connections in incremental order of Q-Factor. Let p is the total no of disjoint OVPN connections.

STEP 4: Compare the required Q-Factor value for a connection request with the Q-Factor values of all the connections arranged in STEP 3 one by one.

STEP 5: If it is satisfied then go to STEP 6, otherwise go to STEP 7.

STEP 6: Check whether the selected OVPN connection is busy or not. If busy the call will be blocked. Go to STEP 1 for next connection request, otherwise go to

STEP 7: Assign the selected OVPN connection for the requested connection. Go to STEP 1 for next connection request.

The algorithm can be explained with the help of Flowchart, which is mentioned in Fig 4.

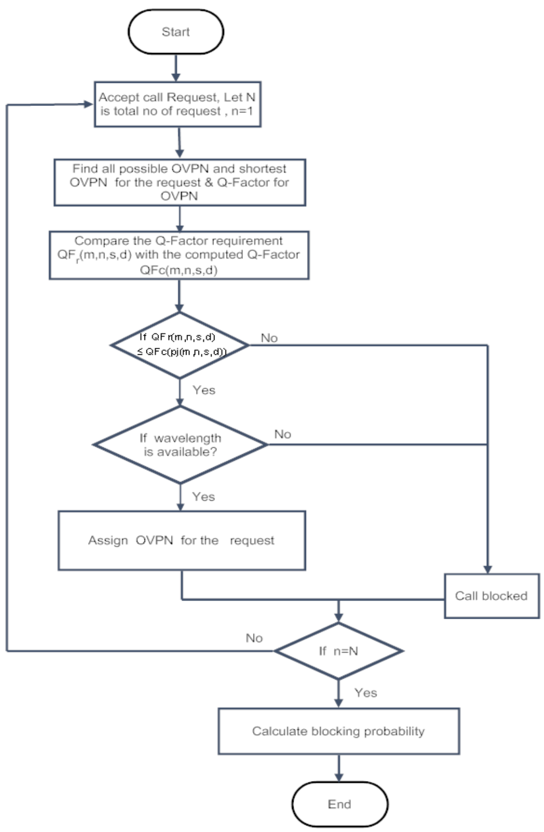


Fig. 3 OVPN connections set up mechanism using shortest path algorithm.

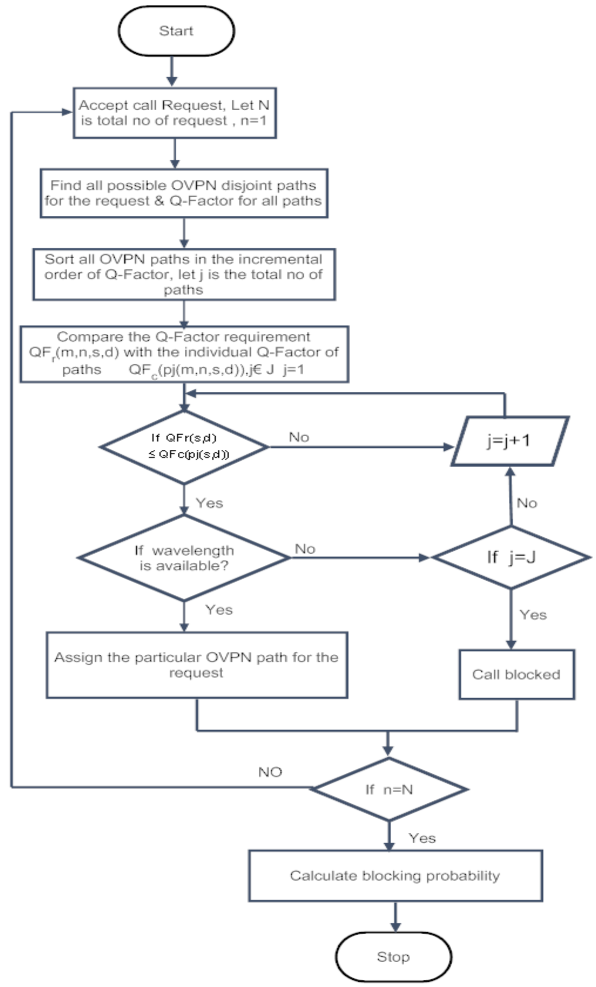


Fig. 4 OVPN connections set up mechanism using disjoint path algorithm.

6. Simulation Results

6.1 Simulation Network Topology and Parameters

The basic network topology used for simulation is shown in Fig 5. The network model can have any number of nodes, but for simulation results we mentioned only for 6 nodes and 10 links. Here we computed three pairs of source and destination nodes (3, 5), (4, 6), and (1, 4) and their possible OVPN connections to choose the best OVPN based on the clients requirement and available resources. In both cases of algorithm, the OVPN connection selection mechanism considers quality parameters such as bandwidth, delay in terms of Q-Factor for finding the best suitable connections. The Q-Factor is nothing but a nominal value in percentage, which represents the quality of the connections. In our simulation work, we use few of the pre-defined parameters, which are mentioned in Table 1. We assumed three different wavelengths for all the links available in the network topology.

Table 1 Parameters used for simulation

`Parameters	Value
Polarization mode dispersion(ps/√km)	0.2
Wavelength (λ) (nm)	1280, 1300, 1330
Pulse broadening factor (δ)	0.1

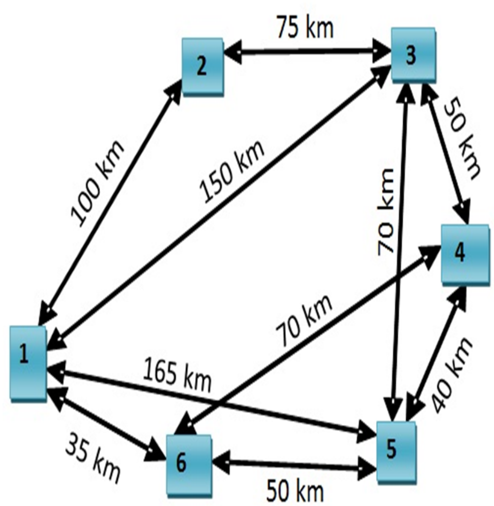


Fig. 5 Network Topology used for simulation

In next section, we mentioned one of our simulation examples, which say more about the OVPN connection setup algorithms and performance analysis.

6.2 Simulation Example

Assume that the network under consideration is a high speed WDM network and we need to setup five OVPN connections connection requests for a particular source 3 and destination 5 with different Q-Factor requirements such as 34, 45, 56, 43 and 24. In this case, we are trying to use the conventional shortest path as well as the disjoint path computation mechanism for OVPN connection finding. For both of the cases computation of Q-Factor for the required connection requests has been done. The simulation results are shown in Table 2.

In shortest OVPN case, we have only one OVPN from source 3 to destination 5 i.e., 3-5 with a computed Q-Factor of 50. Since each link associated with 3 distinct channels / wavelengths, the 3 connection requests with Q-Factor requirement below 50 can be established and only connection request number 3 and 5 are blocked. For wavelength assignment we have followed first fit algorithm.

For disjoint OVPN case, we have 4 OVPNs 3-1-5, 3-4-5, 3-5, 3-2-1-6-5 with computed Q-Factor value of 21, 70, 50 and 35 respectively, each link associated with 3 distinct channel wavelengths. The first connection request has a Q-Factor requirement of 34 and the path 3-2-1-6-5 is assigned for this request which has a computed Q-Factor value of 35. Similar way all connection requests are established by disjoint path algorithm. Hence in this case, the possibility of blocking the connection request will be minimal.

6.3 Simulation Plots

Fig 6a, 6b and 6c shows the graphical representation of required Q-Factor and assigned Q-Factor for different connection requests with the connection reference number.

Table 2 Simulation Results

All possible paths	DOVPN	QF_c	SDOVPN	CRN	QF_r	Using DOVPN			Using SOVPN		
						SOVPN	CRS	BP (%)	SOVPN	CRS	BP (%)
3 -1 -5	3 -1 -5	21									
3 -2 -1 -5											
3 - 4 - 6 – 1-5				1	34	3 -2 -1 -6 -5	1		3-5	1	
3 - 4 -5	3 - 4 -5	70		2	45	3-5	1		3-5	1	
3 -5	3 - 5	50	3-5	3	56	3-4-5	1	0	_	0	40
3 -1 -6 -5				4	43	3-5	1		3-5	1	
3 -2 -1 -6 -5	3 -2 -1 -6 -5	35		5	24	3-2-1-6-5	1		_	0	
3 -4-6-5											
3-1 -6- 4 -5											
3 –1- 6- 4-5											

(**Note**: DOVPN = Disjoint OVPN, QF_c = Computed Q-Factor, SDOVPN = Shortest Distant OVPN, CRN = Connection Request No, QF_r = Required Q-Factor, SOVPN=Selected OVPN, BP=Blocking probability, CRS= Connection Request Status (1= provisioned, 0=blocked)).

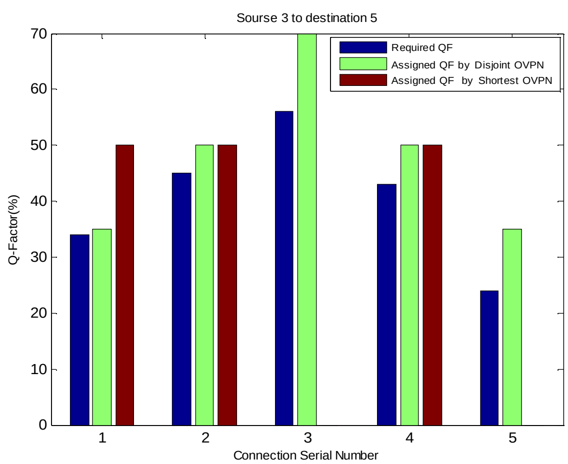
The simulation is done by both cases of Shortest and disjoint OVPN, where, for each connection requests and an OVPN connection are assigned for the particular request. After the selection of an OVPN, the previously computed Q-Factor will be termed as assigned Q-Factor.

Fig 6a, 6b and 6c are for source- destination pair (3, 5), (4, 6) and (1, 4) respectively. For the particular connection request if there is Q-Factor more than or equal to the required Q-Factor and that particular OVPN providing that Q-Factor is free then that OVPN will be assigned for the particular connection request otherwise the call will be blocked.

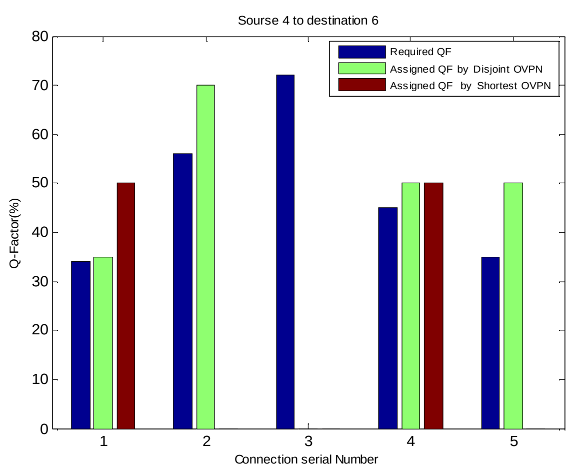
Fig 7a, 7b and 7c shows the plot of blocking probability with the variation of number of connection request for source–destination pair (3, 5), (4, 6) and (1, 4). It takes into account resource blocking i.e. no free resources are available for setting up a connection. Blocking probability is calculated from the number of calls blocked and the total number of calls generated as given in equation 8. A significant improvement in blocking probability is achieved by using disjoint OVPN case, which is our proposed mechanism.

Here our algorithm helps to analyses both bandwidth and delay constraints and determine the best possible path between source destination pair for each connection request. The best path has been selected based on the requirement of the client. Her we have considered all disjoint paths between source and destination instead of the traditional shortest distance concept.

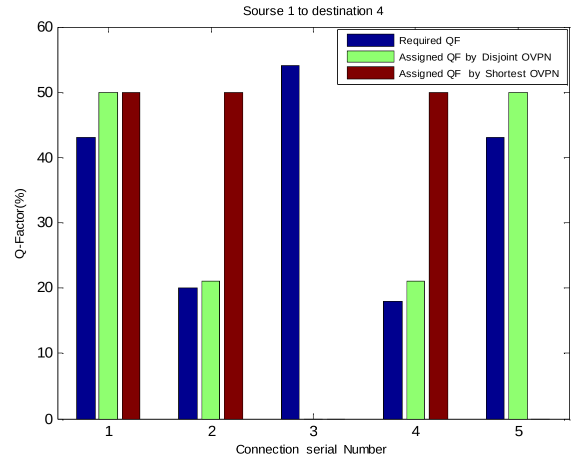
We analyzed and compared the two of the mentioned mechanisms for OVPN connections setup. In case of traditional shortest distance mechanism, it computes only the shortest distance path and then taken into account for various OVPN clients. But in case of disjoint path mechanism, more important goes to the client requirement and all disjoint paths are taken in to consideration for various OVPN clients, which says the availability of more resources as per the requirements. That is the reason, this method can provide more OVPN connections and hence blocking probability is less as compared to shortest path mechanism.



(a) source-destination pair (3, 5)

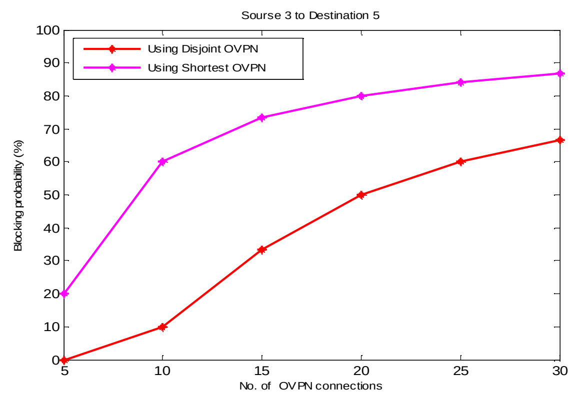


(b) source-destination pair (4,6)

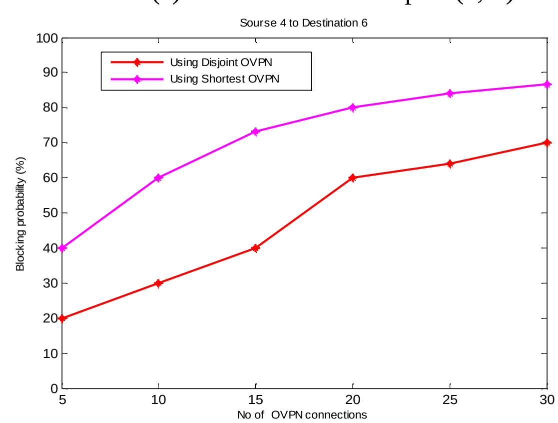


(c) source-destination pair (1,4)

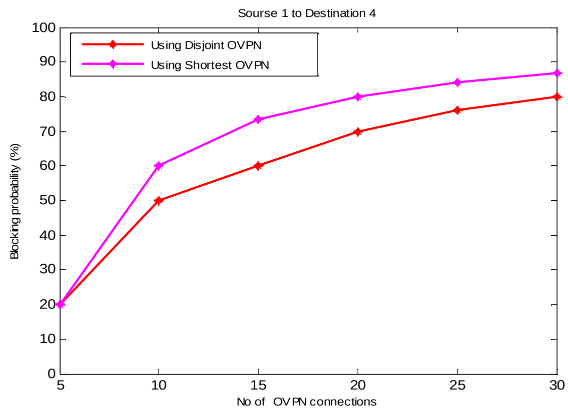
Fig. 6 (a, b, c) Q-Factor (QF) Assignment For connection requests



(a) source-destination pair (3, 5)



(b) source-destination pair (4, 6)



(c) source-destination pair (1, 4)

Fig. 7 (a, b, c) Comparison of Blocking Probability for SP & DP algorithm

7 Conclusion

This paper explain about the efficient OVPN provisioning mechanism over WDM mesh network by considering the effect of PMD which is a most predominant effect in the high speed channels. Here we have considered the PMD effects as a Q-Factor metrics in the physical layer and used the same for the OVPN provisioning in the network layer. We mix-up the network and physical layer concept for the OVPN application in order to provide end-to-end guaranteed service. By applying the concept of shortest path and disjoint path mechanism, we proposed an optimized OVPN connection setup mechanism. We have considered a sig node network topology as per our convenience and simulated our mechanisms. We have compared the simulation results for both the cases of traditional shortest distant and the proposed disjoint path method. In the case of disjoint path algorithm the availability of resources is high, so the blocking probability for the connection requests is significantly improved compared to the shortest distance method. The proposed mechanism for OVPN provisioning is based on the Q-Factor requirement of the client and the available resources, which can provide a guaranteed source to the end customer. Also this can be used for route restoration during link failure time. In future we are planning to extend our work for the enhancement of OVPN application during link/path failure conditions. The link/path failure might create lots of redundancy for OVPN provisioning and de-provisioning because of heavy traffic.

Acknowledgements

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